Designing Coal-Haul Roads for Good Drainage

WELDON K. WEIGLE

CENTRAL STATES FOREST EXPERIMENT STATION
U. S. DEPT. AGRICULTURE — FOREST SERVICE

ered

nois

of

Central States Forest Experiment Station, U.S. Dept. of Agriculture
Forest Service, 111 Old Federal Building, Columbus, Ohio
R. D. Lane, Director
1965

Designing Coal-Haul Roads for Good Drainage

WELDON K. WEIGLE[1]

A well-built road is like a house, it requires a good foundation, a dry basement, and a roof. Significantly, all these characteristics have to do with water, or more specifically, drainage. How good a road is then depends greatly upon how well it is drained.

This guide is intended to help the small coal company without an engineering staff to plan, locate, construct, and maintain its roads — with special emphasis on drainage. If more detailed information is required, several sources are listed under references at the end of the book.

---

[1]Civil Engineer, U.S. Forest Service, Central States Forest Experiment Station, Berea, Kentucky, field office, maintained in cooperation with Berea College.

TYPE OF ROAD

First, you must decide what type of road to build: width (one or two lanes or maybe a single lane with turnouts), the kind of surface, the grade, and the sharpness of curves, and so on. In making this decision consider initial cost, expected life, maintenance, and unit cost of hauling. Each of these must be balanced against the others to achieve the desired quality road at a minimum cost. Design your road to handle all the production your mining equipment normally turns out.[2] A road of higher or lower quality will lose money.

Estimate maintenance costs for each type of road including equipment, labor, and materials. Periods of no use due to adverse weather, which will vary with type of road, should also be estimated. The design of your road will affect the amount of coal that can be hauled by one truck in a day. Therefore, building a low-quality road might limit your total production per day.

LOCATION

The time spent in the office selecting possible road locations on topographic maps and aerial photos will be saved several times over in the field. From maps and photos you can determine slope aspect and grade and pinpoint topographic features to be avoided.

Slope aspect is the direction a slope faces. West and south slopes dry out earlier in the spring and stay dry longer in the fall. Following a rain you can also expect faster drying on these slopes.

The slope or incline of a road is called grade and is usually expressed in percent. A 10-percent grade is one that goes up or down 10 feet for every 100 feet of length. From topographic

---

[2]Byrne, J. J., Nelson, R. J., and Googins, P. H. Logging road handbook: the effect of road design on hauling costs. U.S. Dept. Agr. Handb. 183, 65 pp., illus. 1960.

maps the difference in elevation and the distance between two points may be determined. Dividing the difference in elevation by length of road will give the sustained grade of the proposed road between points.

A sustained grade of 10 percent is about the steepest that can be adequately and economically drained but a sustained grade of less than 10 percent is more desirable. Minimum grades shorten round-trip time for trucks, which means more loads per day. Occasionally pitch grades of 5 percent more than the sustained grade for less than 300 feet can be used to avoid obstacles.

Wet areas, rock ledges, and streams are shown on topographic maps. Wet areas are not suitable for a road base and require special treatment, such as draining and filling with borrow material. Rock is costly to build roads on because of the blasting and/or ripping involved. Roads should be located far enough from streams to prevent any fill from spilling into them and to prevent high water from undercutting the fill slope. Try to minimize the number of stream crossings to reduce your bridging cost.

After tentative routes have been located on maps, these routes should be walked on the ground to determine the final location. The location party, usually two men, can flag the centerline of the road using an Abney Hand Level to maintain the grade (Appendix). It is best to start flagging from the upper end of the road and work downhill on the desired grade, hanging pieces of high-visibility flagging on convenient trees or brush. Minor adjustments in grade or line should be made by the locating party instead of the construction crew.

Trees and brush cut from the right-of-way should be placed in a windrow at or below the toe of the fill. Here this material serves as a filter to reduce sedimentation caused by erosion, and to reduce slides and slumps in the fill. Trees and brush buried in the fill contribute to failures in two ways: (1) they serve as a drainage passage for water, which helps to saturate the materials, and (2) they decay leaving voids in the soil, which causes settling and/or slumping.

Clear 6 feet beyond the cut bank and 3 feet beyond the toe of the fill to help the roadbed dry out faster after a rain (fig. 1). Cutting rather than bulldozing, is recommended because the ground litter isn't disturbed, and erosion is reduced.

To further reduce the sediment load of a stream, locate the road so as to leave a strip of undisturbed vegetation at least 50 feet wide between the toe of the fill and the stream. As the steepness of slope increases so should the width of filter strip (table 1). Avoid changing the stream channel because this will have an adverse effect on fish environment.

Table 1.--Width of filter strip in relation to steepness of slope between road and stream

Slope of land between road and stream (percent)	Width of filter strip
	Feet
0	50
10	50
20	65
30	85
40	105
50	125
60	145
70	165

Switchbacks can be used to gain road elevation in a confined area but they should be used with discretion. Not only do they require special drainage systems, but they are expensive to build and create bottlenecks in traffic (fig. 2). Trucks with a capacity of 30 tons require a 75-foot-minimum radius of curvature but a larger radius (at least 200 feet) is recommended for a smoother flow of traffic.

The actual construction should always be done in dry weather. Wet material in the subbase and base of the road will not dry out and may heave if this material freezes the following winter.

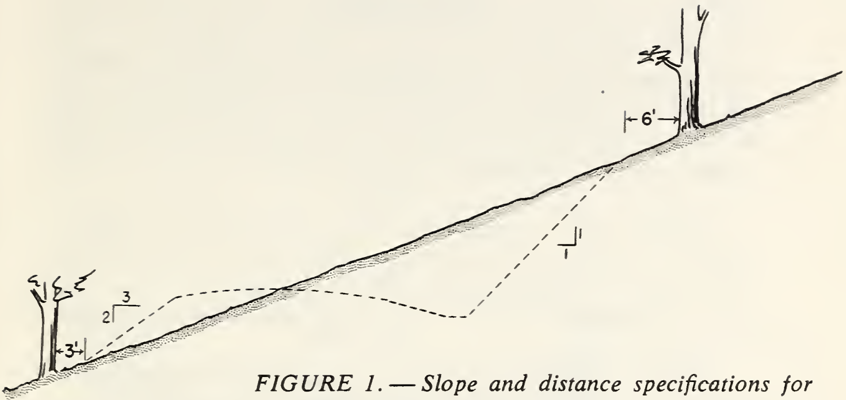


FIGURE 1. — Slope and distance specifications for roadbed clearing. If backslope is in rock, a 1:4 slope may be used instead of 1:1. Two extra feet of road width should be allowed on fill slopes for weathering.

FIGURE 2. — Switchback. Allow at least 200 feet curvature radius if at all possible.

DRAINAGE

It is poor economy to skimp on drainage. On an unpaved road, water acts as a solvent that softens and dissolves the material used in road construction. The clay portion and water produce a doughlike substance at first, and eventually, a soupy mixture that has no bearing capacity.

Water in the subbase of a silt or clay-silt soil, which is common in eastern United States, may result in frost heaving if the subbase freezes. This results in a breakup of the road surface during the spring thaw and increases maintenance costs.

Make a thorough map study of the area noting the drainage areas, permanent streams, intermittent streams, wet areas, springs, general vegetative cover, and steepness of slopes. During the field reconnaissance note the location of drainage problems and estimate the size and type of drainage structures needed. Then you can order the right materials before you start to build.

Continuous and Intermittent Land Drainage

This part of a drainage system is designed for streams carrying continuous or intermittent flow. Such channels are easily recognized in the field.

Culverts

The most common method of draining channel flow is with a culvert. Culverts can be lumber, log, concrete, steel, aluminum, or clay. Culvert material should be selected on the basis of expected life, load-carrying requirements, and ease of installation. In acid water, metal and concrete culverts should be protected with an asphalt or vitrified-clay lining.

If possible, a culvert should be installed in the natural drainage channel and on the same grade as the stream. A culvert inlet should be placed on or below, but not above, the streambed. Avoid filling under a culvert to bring it up to grade. Seat the culvert on firm ground and compact the earth at least

halfway up the side of the pipe to prevent water from leaking around it. Adequate cover is needed, the rule being a minimum of 1 foot or half the culvert diameter, whichever is greater (fig. 3). If adequate cover cannot be achieved then a pipe arch or two smaller culverts should be installed. The cover must also be compacted to prevent settling in the road. If erosion of the inlet end is a problem a headwall must be provided. Sandbags, logs, concrete, or hand-placed riprap are suitable.

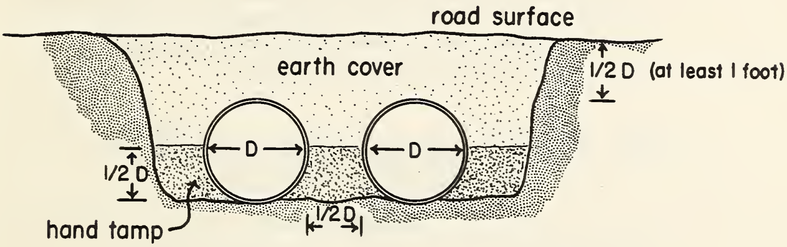


FIGURE 3. — Culvert installation. Earth should be hand-tamped at least half way up the side of the pipe. Space between pipes in a multiple culvert should be half the pipe diameter. Earth cover over pipes should also be half the culvert diameter in depth but not less than 1 foot.

Normally a culvert is placed on a 2- to 4-percent grade to prevent clogging. Flow velocity should be more than 2.5 feet per second to prevent sedimentation but less than 8 feet per second to prevent scouring. Generally, a grade of 2 percent is sufficient to obtain velocity in this range. The outlet end of a culvert should be placed at or below the toe of the fill and an apron of rock should be provided for the outflow to spill on.

A hasty method for estimating the cross-sectional area required for a culvert is to double the channel area (fig. 4). This method does not take into account size, shape, and slope of the area; surface vegetation; soil condition; or rainfall intensity. It considers only outlet size. This hasty calculation is used as a guide when time does not permit a more exact method.

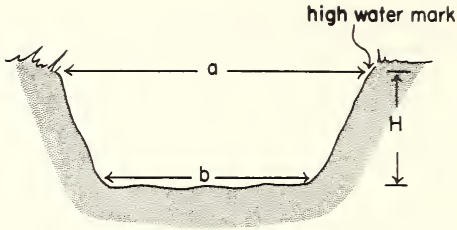


FIGURE 4. — The cross-sectional area needed for a culvert can easily be computed by adding the widths of the top and bottom of the ditch and multiplying by the height — $(a + b) H$. This is equal to double the cross-sectional area of the channel.

Table 2.--Required culvert opening (computed by a modified Talbot's formula

(In square feet)

Drainage area (acres)	Open land	Forest land
2	1.2	0.9
5	2.3	1.7
10	3.9	2.8
20	6.7	4.8
30	9.0	6.4
40	11.1	8.0
50	12.5	8.9
75	17.8	12.7
100	22.1	15.8
150	30.0	21.5
200	37.2	26.6
300	50.5	36.1
400	61.7	44.1
500	74.2	53.0
600	85.0	61.0
800	106.0	76.0
1,000	125.0	86.0
1,200	143.0	102.0
1,500	169.0	121.0
2,000	209.0	150.0
2,500	247.0	177.0
3,000	284.0	203.0
4,000	352.0	252.0

Talbot's formula provides another method for estimating the size of culvert needed. This formula uses a 4-inch-per-hour rainfall intensity and the slope and size of the area drained. For our purposes the slope need not be considered. Calculate the size of the area drained in acres and decide whether it is open or forested land. The formula then gives you the cross-sectional area of the drainage structure that is needed when these factors are known (table 2). Finally, find the diameter of culvert needed to provide the required cross-sectional area (table 3).

Table 3.--Square feet of opening for various diameters of culvert

Pipe diameter (inches)	Waterway area
	Square feet
8	0.35
10	.55
12	.79
15	1.23
18	1.77
21	2.41
24	3.14
30	4.91
36	7.07
42	9.62
48	12.57
54	15.90
60	19.64
66	23.76
72	28.27
78	33.18
84	38.49

Bridges

If you have to cross a large channel a bridge is probably your answer. A high-water bridge should be favored over a low-water bridge because it can be used year round. If a low-water crossing is all that is needed a series of culverts will provide a better crossing than a low bridge.

A variety of building materials can be used, but in eastern Appalachia log or treated-timber bridges are the most common. Care must be taken in choosing the proper size and spacing of log stringers (table 4). A bridge should cross a stream at right angles to the streamflow and provide sufficient clearance to accommodate the high water.

Table 4.--Safe truck loadings on timber-stringer bridges

(In tons)

Clear span (feet)	Center-to-center spacing (inches) 6	12	18	24	30	36	42
	6-INCH-DIAMETER STRINGER						
8	9.2	4.6	3.1	2.3	1.8	1.5	
10	7.5	3.7	2.5	1.8	1.5	1.2	
12	6.2	3.1	2.1	1.6	1.2	1.0	
	8-INCH-DIAMETER STRINGER						
8		11.0	7.4	5.5	4.4	3.7	
10		8.8	5.9	4.4	3.5	2.9	
12		7.4	4.9	3.7	2.9	2.5	
14		6.0	4.0	3.0	2.4	2.0	
16		5.2	3.5	2.6	2.1	1.7	
18		4.7	3.1	2.3	1.8	1.5	
	10-INCH-DIAMETER STRINGER						
8		21.6	14.4	10.7	8.6	7.3	
10		17.3	11.5	8.6	6.9	5.7	
12		14.4	9.6	7.2	5.7	4.8	
14		11.7	7.8	5.9	4.7	3.9	
16		10.2	6.8	5.1	4.1	3.4	
18		9.1	6.1	4.5	3.6	3.0	
20		7.8	5.2	3.9	3.1	2.6	
22		7.0	4.7	3.5	2.8	2.3	
24		6.5	4.3	3.2	2.6	2.1	

Table 4.--Safe truck loadings on timber-stringer bridges (con.)

(In tons)

Clear span (feet)	Center-to-center spacing (inches) 6	12	18	24	30	36	42
12-INCH-DIAMETER STRINGER							
8		37.2	24.9	18.7	14.9	12.4	
10		29.9	19.8	15.0	11.9	9.9	
12		24.9	16.6	12.4	9.9	8.3	
14		20.3	13.5	10.1	8.1	6.8	
16		17.8	11.8	8.9	7.1	5.9	
18		15.8	10.5	7.9	6.3	5.2	
20		13.4	8.9	6.7	5.3	4.5	
22		12.2	8.1	6.1	4.9	4.0	
24		11.2	7.5	5.6	4.5	3.8	
26		9.7	6.5	4.9	3.9	3.2	
28		9.1	6.0	4.5	3.6	3.0	
30		8.5	5.6	4.2	3.4	2.8	
14-INCH-DIAMETER STRINGER							
8			39.6	29.7	23.7	19.8	14.7
10			31.7	23.7	19.0	15.8	13.5
12			26.4	19.8	15.8	13.2	11.3
14			21.5	16.1	12.9	10.7	9.2
16			18.8	14.1	11.3	9.4	8.1
18			16.7	12.5	10.0	8.4	7.2
20			14.3	10.7	8.6	7.1	6.1
22			13.0	9.7	7.8	6.5	5.6
24			11.9	8.9	7.1	5.9	5.1
26			10.4	7.8	6.2	5.2	4.4
28			9.6	7.2	5.8	4.8	4.1
30			9.0	6.7	5.4	4.5	3.8
16-INCH-DIAMETER STRINGER							
8			59.0	44.3	35.4	29.6	25.3
10			47.3	35.4	28.4	23.6	20.3
12			39.4	29.5	23.6	19.7	16.9
14			32.1	24.1	19.3	16.0	13.7
16			28.1	21.1	16.8	14.0	12.0
18			25.0	18.7	15.0	12.5	10.7
20			21.3	16.0	12.7	10.6	9.1
22			19.3	14.5	11.6	9.7	8.3
24			17.7	13.3	10.6	8.9	7.6
26			15.5	11.6	9.3	7.7	6.3
28			14.3	10.7	8.6	7.2	6.1
30			13.4	10.0	8.1	6.7	5.7

Notes: (1) Values based on red or white oak, pine, cedar or hickory. For yellow-poplar reduce values by 20 percent.

(2) Table values are in tons assuming 3-inch by 12-inch floor planks and 3-inch run planks in good condition or 2-inch by 4-inch solid laminated deck without run planks.

(3) For plank-floor bridges without run planks reduce capacity by 20 percent.

(4) Diameter is at midspan of stringer.

Fords

A ford is a stream crossing using the streambed as a roadway. A suitable ford is one with a solid rock bottom and rock streambanks. The approaches should be sufficiently steep to prevent high water from flooding the road but gentle enough to allow easy access by vehicles (fig. 5). The use of log corduroy or rock riprap on the banks and stream bottom is recommended when the crossing is to be made under unsuitable conditions.

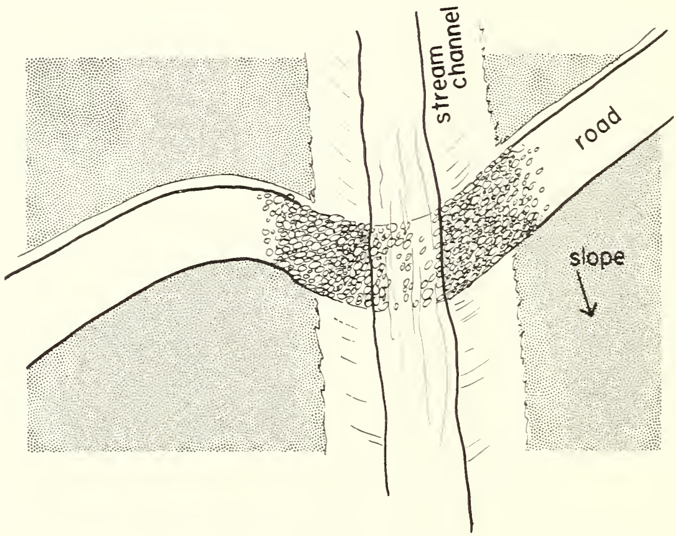


FIGURE 5.—Ford. On sloping land road should curve upward at both ends of the ford so that during high water stream will not run down the road.

Road Surface Drainage

Surface drainage provides for removal of water from road surfaces and for the collection and removal of water from surrounding terrain before it reaches the improved surface. The following discussion covers the common method of surface drainage. Selection of a method or combination of methods should be based on type and amount of traffic, expected period of use, and maintenance costs.

Surfacing

The surface or "roof" of your road must be built to shed water as well as carry the intended load. If you need an all-weather road sound surfacing material must be obtained. Suitable material is not always easy to find. Your local highway district can tell you what is available in your area.

A variety of materials can be used for surfacing — slag, crushed stone, tuff, streamgravel, and many others. The material chosen should be sound and durable. A poor base material such as a fat clay may be upgraded by mixing it with rock or stream gravel and then adding sodium or calcium chloride as a stabilizing agent. When the mixture is shaped and compacted a tight, dense, and dust-free surface results.[3,4,5] Paving a road with asphalt may be economical if a large volume of coal is to be moved and long periods of shutdown can otherwise be expected due to wet weather.

Insloping a road at the rate of ½ inch per foot of width is a common method of handling storm runoff from the road surface. A ditch is necessary with this method of drainage and ditch-relief culverts (see below), spaced at proper intervals, must be included to prevent overflowing and scouring of the ditch. Crowning a road to move water from the surface to a drain ditch is a better way to provide surface drainage. On a gravel or dirt road a crown of ½ to ¾ inch per foot of width (measured both ways from centerline) is adequate.

---

[3]Calcium Chloride Institute. Maintenance tips for unpaved roads. 36 pp., illus. Washington, D. C. [n. d.]

[4]Calcium Chloride Institute. Calcium chloride for stabilization of bases and wearing courses. 34 pp., illus. Washington, D. C. 1959.

[5]Salt Institute. Salt for road stabilization. 24 pp., illus. Chicago, Ill. [n. d.]

Ditches

The most common surface drain is a ditch along the upper side of the road, usually on the same grade as the road. The slope of the ditchsides should be about 1:4 (1 foot rise for every 4 feet of run) (fig. 6).

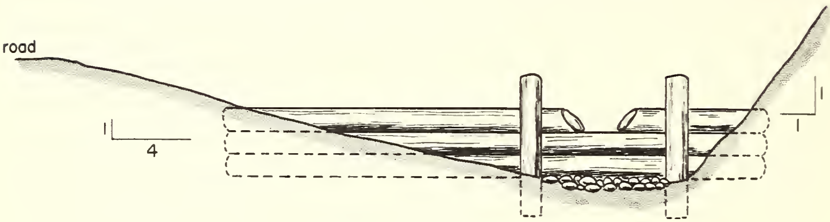


FIGURE 6. — Check dam.

Two types of ditches are common, V-shaped and trapezoidal. The trapezoidal ditch has a greater capacity than the V-shaped ditch of the same depth but is more difficult to construct and maintain. The minimum size practical to construct is 1½ feet deep by 2 feet wide at the bottom. Construction of trapezoidal ditches requires a special ditcher.

Erosion is likely to occur during a heavy rain in any ditch with a grade of over 4 percent, regardless of the soil type. The deepening of a ditch by erosion may be no problem if the road will be used only a short time. If a road is to be used for a long period, ditch erosion must be controlled. One remedy is to line the ditch with stone or other riprap material. Ditches with grades greater than 10 percent should be paved to prevent erosion.

Two simple structures may also be used, either singly or in combination, to prevent ditch erosion — check dams and ditch-relief culverts. Check dams are usually designed to reduce the grade below 4 percent, which has the effect of changing

the streamflow from a torrent to a series of gentle flows between dams. The height and spacing can be varied to obtain the desired slope (table 5).

When building check dams the spillway must have a definite weir or notch-type outlet. The bottom of the notch is the determining point for grade calculations. The sides and bottom of the dam should extend 6 inches into the ditch line and the spillway should be protected with rock riprap (fig. 6). The upstream face of the dam should also be protected from scouring. The check dam can be made out of steel, concrete, logs, rocks, sandbags, or earth (if the earth is well protected from scouring).

Table 5.--Check dam spacing for various dam heights and stream grades

(In feet)

Difference in grade (A - B) (in percent)	Dam height (H) in feet				
	1	1-1/2	2	2-1/2	3
1/2	200	300	400	500	600
1	100	150	200	250	300
1-1/2	67	100	133	167	200
2	50	75	100	125	150
2-1/2	40	60	80	100	120
3	33	50	67	83	100
3-1/2	29	43	57	71	86
4	25	38	50	63	75
4-1/2	--	33	44	56	67

Formula: $\text{spacing} = \frac{100\ H}{A - B}$

where

H = height of dam
A = grade of existing stream level in percent
B = grade of proposed stream level in percent

Ditch-relief culverts are used to move water under the road before the flow gains sufficient volume or head to erode the ditch. On an 8- to 10-percent grade the culverts should be spaced 200 to 300 feet apart while on a 5-percent grade, about 500 feet apart. These figures will vary locally depending on type of soil, amount of rainfall, and width of road. Ditch-relief culverts should cross the road at about a 30-degree angle (culvert outlet downgrade about half the road width) to provide better entrance conditions on steep slopes (fig. 7). Ditch-relief culverts can also be used in conjunction with check dams — one culvert behind each dam.

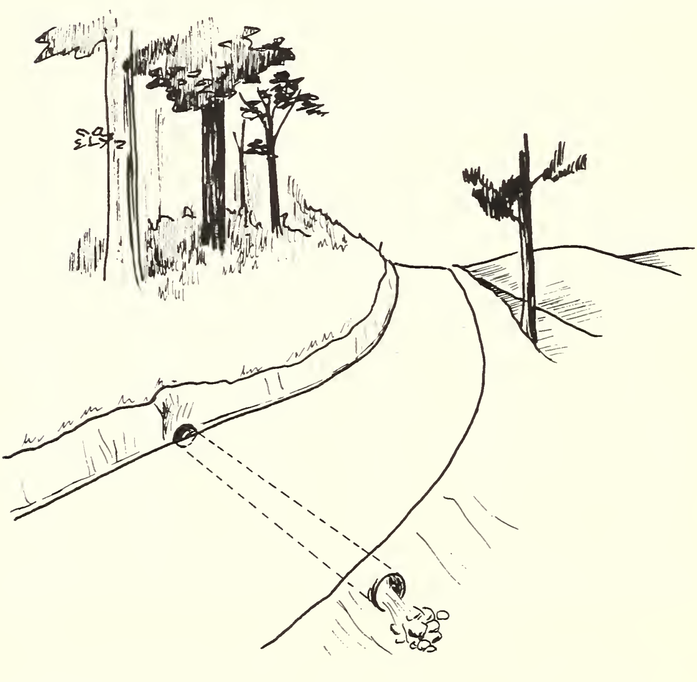


FIGURE 7. — Ditch-relief culvert. Culvert should cross road at about a 30-degree angle downgrade.

A structure for removing water from the road surface is the open-top culvert. The initial cost is low but such culverts are difficult to keep clean, they must be carefully installed and bedded, and they break up under heavy traffic. Two designs are shown (fig. 8) along with the recommended spacing (table 6) and the installation procedure.

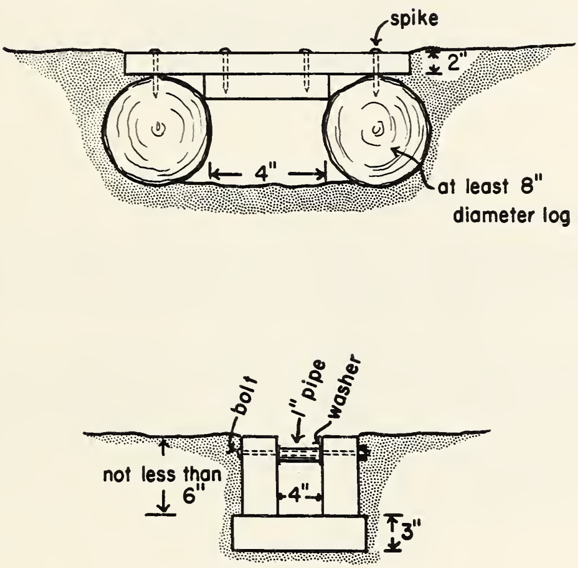


FIGURE 8. — Open-top culverts. One type (top) consists of two logs held apart and parallel by 2-inch planks spiked to each end of the logs. Another type (bottom) is made up of 3-inch timbers assembled in a trough-shape. Spacers of 1-inch pipe are bolted along upper edge at about 4-foot intervals for rigidity. Like ditch-relief culverts, open-top culverts should cross road at a 30-degree angle downgrade.

Table 6.--Spacing of open-top culverts

Road grade (percent)	Spacing
	Feet
2-5	300-800
6-10	200-300
11-15	100-200

Note: Spacing must be based on local conditions and the type of soil and the amount of watershed cover present in the area.

Subsurface Road Drainage

A high water table, seep, or spring will cause soft spots in a road. To correct these the wet material must be removed and replaced with a suitable drainage structure.

One method is to remove the material, leaving a trench sloping from the inside to the outside of the road. Fill the trench with rock, progressing from coarse to fine to within a foot of finished grade and then place a suitable base material, well compacted, over the porous material.

Road Maintenance

To keep a road at a desired quality and properly drained maintenance is required. Maintenance is an ever-increasing cost that can be minimized in two ways: (1) good initial construction, and (2) timely repair done in a proper manner.

Grading

Grading is done to restore the crown and smooth the surface of the road. Shaping should be done in the spring after the road has lost its heavy moisture but before it becomes

hard and dry. Routine smoothing during the summer should be done after a rain has moistened the road but not made it slippery with mud.

When grading, the crown of ½ inch to ¾ inch per foot must be maintained so that the road will shed storm runoff. You must not cross the road crown with the blade. The first blade pass should be from the road edge toward the road center, the second pass from the road center to the road edge. Most roads can be graded by making two round trips.

During routine maintenance of ditches do not undercut the backslope because this will cause sloughing into the ditch and result in washout and bank erosion.

Dust Control

Excessive dust is a driving hazard and it is hard on equipment. Dust increases equipment maintenance costs and decreases the useful life of the equipment. It also represents a loss in surface material and hence a deterioration of the road. Calcium chloride and sodium chloride are the least expensive and most effective materials for controlling dust. After the initial spring shaping of your road apply 1 pound per square yard of road surface. A lime drill can be used to apply it uniformly. At least twice more during the summer months an application of ½ pound per square yard should be applied. All salt applications should be made after shaping is completed but while the ground surface is still moist.

Drainage Facilities

All ditches, culverts, and bridges must be kept clean and in good repair if they are to serve their purpose. At no time should grading leave a berm of earth between the roadbed and the ditch. If seasonal shutdown is planned, provisions should be made to maintain all drainage facilities during that period. Particular attention should be given to removing debris from culvert inlets.

Bedding Down a Road

When a haul road is abandoned steps should be taken immediately to minimize erosion and establish a vegetative cover.

Storm water is best controlled by using water bars. Water bars may be either the ditch and earth berm type (fig. 9) or the log type. If the road is to be used occasionally, the log type is recommended because the earth berm is useless once wheel tracks are made in it. Proper spacing is important (table 7). A water bar must be placed at the head of all pitch grades regardless of other spacing.

If berms are to be constructed by machine you should begin at the top of the hill and work down to minimize the number of equipment crossings. Even so, some handwork will be needed to eliminate equipment tracks through the earth berms.

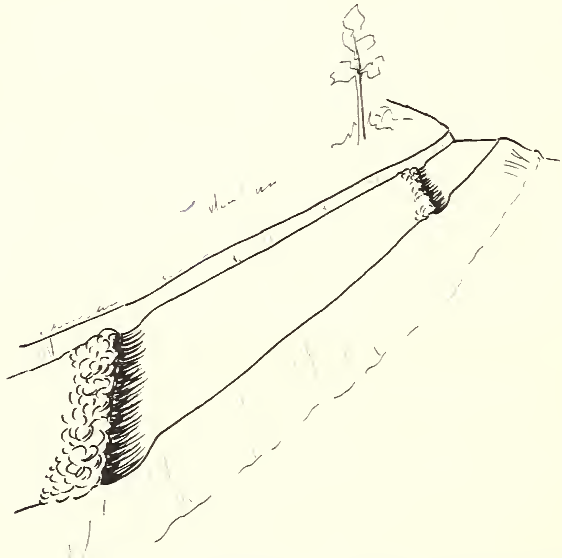


FIGURE 9. — Water bar (earth-berm type). Like culverts, water bars should cross road at a 30-degree angle downgrade.

Table 7.--Water bar spacing

Road grade (percent)	Spacing
	Feet
2	250
5	135
10	80
15	60
20	45

Drainages must be kept open. If the road is not to be used, all bridges and culverts should be removed before they become plugged. If the road must be kept open, some provision must be made for permanent drainage. Bridges and large culverts can be replaced by fords, but most small corrugated-metal-pipe culverts should be left in place.

A cover of grass should be established on the roadbed as soon as possible. Later, you may introduce shrubs and trees. Scarifying the roadbed will provide a better seedbed for grasses. To lessen the impact of rain, slash or tree litter should be placed between water bars on the roadbed after seeding. Your county agent, Soil Conservation district, or service forester can help you select the proper grasses for your area and planting season.

If possible, a bedded-down road should be closed to traffic because wheel ruts in the water bars will destroy their effectiveness. In addition, possible road users must be warned of hazards. Some sort of barricade should be considered at the ends of the road to limit use to emergency vehicles.

REFERENCES

Armco Drainage and Metal Products, Inc.
1958. Handbook of drainage and construction products. 529 pp., illus. Middletown, Ohio.

Dalton, J. C.
1950. Maintenance of county and rural roads. Idaho Univ. Engin. Expt. Sta. Bul. 7, 58 pp., illus.

Department of the Army.
1957. Roads and airfields. TM 5-250, 704 pp., illus.

Haussman, Richard F.
1960. Permanent logging roads for better woodlot management. U.S. Forest Serv. East. Region, 38 pp., illus. Upper Darby, Pa.

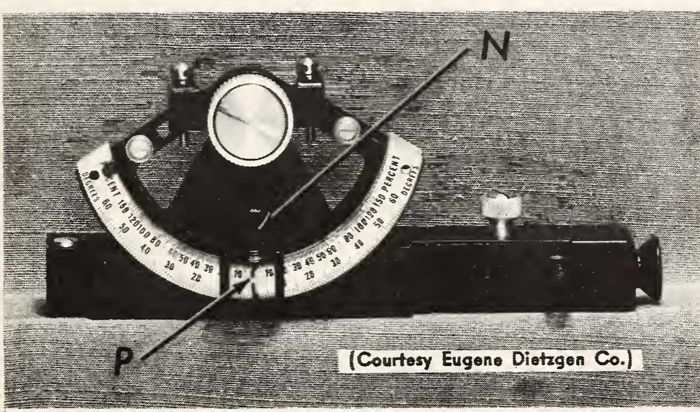
Oglesby, D. H., and Hewes, L. I.
1963. Highway engineering. 783 pp., illus. New York: John Wiley and Sons, Inc.

APPENDIX

To use the Abney Hand Level to maintain the desired grade when laying out a road:

Loosen nut (N) over pointer (P) and move pointer to desired grade (top row of figures). (Move pointer clockwise if you're working uphill and counter clockwise if you're going downhill.)

Sight through eyepiece at flag held at eye height. Signal flagman to move up or downhill until flag is in your line of sight at the same time the bubble is centered on the cross hair.



(Courtesy Eugene Dietzgen Co.)

The Forest Service of the U.S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.

NATIONAL FOREST SYSTEM · COOPERATIVE FORESTRY · FORESTRY RESEARCH

1905 - 1965 FOREST SERVICE 60 YEARS